PHYTOTOXICOLOGY ASSESSMENT INVESTIGATION IN THE VICINITY OF AMERICAN-STANDARD, CAMBRIDGE--1990

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Report prepared by:

G.N. Vasiloff
Phytotoxicology Section
Air Resources Branch
Ontario Ministry of the Environment

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Background

A complaint of severe vegetation injury was investigated in 1987 by the Phytotoxicology Section at a small park in the city of Cambridge. The park is located directly across the Speed River from the American-Standard factory. Chemical analysis of the injured foliage showed that concentrations of boron, and in some cases fluoride, were excessive or elevated. Available boron (hot water soluble) in 0-5 cm soil sampled at the park exceeded the 1 ppm concentration considered to be phytotoxic. Because of the boron-like foliar injury and the high boron concentrations found in the analyzed foliar tissue, it was suspected that the nearby American-Standard plant was the source of boron and fluoride emissions. This suspicion was based on the knowledge that compounds containing boron, fluoride and other elements are used by the company during their coating and finishing processes.

As a result of the complaint investigation findings, Phytotoxicology investigators conducted a visual survey of other vegetation at a number of locations in the vicinity of the American-Standard plant in 1987. Boron and/or fluoride foliar injury symptoms were found at a number of locations close to the factory. The severity of the injury symptoms lessened and then disappeared with increased distance from the plant.

Based on the complaint investigation results and the visual survey, Ron McKnight of the Ministry's Cambridge office approached officials at American-Standard to discuss factory emissions. As a result of these discussions, American-Standard agreed to install a water bath abatement system on their spray booths that are used to apply an enamel cover coat. By December of 1988, the water bath system was installed and in operation. Subsequent to the installation, source tests within the stack were conducted. A report containing the test results was forwarded to the Ministry's Emission Technology & Regulation Development Section in Toronto and is currently being reviewed.

In 1989, the Phytotoxicology Section initiated a formal vegetation and soil survey investigation at selected sites around the American-Standard plant. Severe foliar injury, characteristic of that induced by boron, was observed on a variety of vegetation species at sites close to the American-Standard plant. The severity and incidence of injury declined sharply in all directions with increased distance from the plant. Chemical analysis results for sampled foliage indicated that boron concentrations were above the Phytotoxicology Upper Limit of Normal (ULN) guideline at 11 of the 17 survey sites. In addition, concentrations of fluoride, barium, titanium, zinc, nickel and lead were elevated or excessive at sites close to the plant.

Concentrations of available boron (hot water soluble) above 1 ppm (considered to be phytotoxic) were found in 0-5 cm soil at 5 sites and 2 sites in soil collected from a depth of 25-30 cm. Excessive total boron concentrations were found in 0-5 cm soil at 8 survey sites.

At sites close to the plant, elevated or excessive concentrations of fluoride, titanium, zinc, copper, nickel and lead were present in 0-5 cm soil.

1990 Phytotoxicology Survey

On 30 August 1990, Phytotoxicology investigators returned to the Cambridge area and conducted a vegetation survey at established sites in the vicinity of the American Standard plant. Vegetation at the 17 sites initially established in 1989 was examined in 1990 for evidence of injury and sampled for chemical analysis. In order to provide better survey coverage west and northwest of the American Standard plant, three new sites (19-21) were added for the 1990 survey. In the 1989 survey report (PIBS No. 1542), the control amur maple listed as being at Site 18, should have been shown as being at Site 22. The locations of all sites (except 22) are shown in the attached figure. Site 22 is located in a city park, located near the intersection of Water St. and Parkhill Road in Cambridge. The locations and directions of some survey sites from American-Standard were stated incorrectly in the 1989 report - these have been corrected in the 1990 report.

At each site, either silver maple, Norway maple or both were utilized for observational and sampling purposes. At Sites 1 and 16, neither of the two preferred species were available, and therefore, amur maple was substituted. Vegetation at each site was examined for air pollution injury symptoms and the observations were recorded. Injury severity ratings and the percentage of injured foliage at each site were the main parameters assessed.

Following the observational phase of the survey, and depending on availability, silver, Norway or amur maple foliage was collected in duplicate for chemical analysis. At each location, foliage was collected from the aspect of the sample tree(s) facing the American Standard plant. At sites where severe foliar injury was encountered, samples of leaves that displayed typical injury symptoms were collected for retention in the herbarium.

The foliage samples were submitted to the Phytotoxicology laboratory to be processed as unwashed according to standard methods. Processed samples were submitted to the Ministry's Inorganic Trace Contaminants laboratory for boron, fluoride, barium, titanium, sodium, nickel, zinc, lead, magnesium, copper, sulphur and iron analysis.

Visual Observations

Table 1 is a summary of the 1990 vegetation injury symptoms. Injury to vegetation was most severe and extensive at sites closest to the American Standard plant (Sites 1, 2, 5, 8, 14 and 16). In general, most injury was observed on the terminal, marginal and intercostal areas of plant foliage. The injury symptoms were characteristic of boron and, to a lesser extent, fluoride toxicity. With increased distance in all directions from American Standard, injury severity and the percentage of foliage affected declined.

Chemical Analysis Results

Concentrations of 12 elements detected in foliage sampled at 21 of the 22 survey sites are shown in Tables 2-13. The data are averages for duplicate samples. Concentrations that exceed their respective Phytotoxicology Upper Limit of Normal guideline are underlined. The rationale behind the method for determining ULN guidelines appears in the attached appendix. Also included in the tables are the mean concentrations from common collection sites in 1989 and 1990. These annual concentrations were examined statistically using paired t tests in order to determine if environmental quality (as indicated by foliar chemistry) has improved significantly in 1990 relative to 1989, as the abatement strategy initiated in 1987 was implemented.

Boron concentrations detected in both the 1989 and 1990 foliage are summarized in Table 2. In the 1989 foliage, boron concentrations exceeded the ULN guideline at 11 survey sites, with the highest concentrations occurring at Site 16 (1300 ppm) and Site 1 (895 ppm). In the 1990 foliage, excessive boron concentrations in foliage were found at 8 sites. The highest value (1050 ppm) was again found at Site 16. Boron concentrations in the 1990 foliage, however, were relatively high again at Site 1 (525 ppm), but also Sites 2 and Site 8.

Compared to 1989, boron concentrations in the 1990 foliage were lower at 13 sites but higher at 4 sites. On average, foliar boron concentrations were lower in 1990 than in 1989 (271 ppm vs 339 ppm, respectively), although the reduction was not highly significant ($p=0.03$). This marginal reduction in boron levels in light of the recent abatement action may be due to the fact that soil at some sites close to the American Standard plant contain excessive concentrations of available boron. Plant roots are able to absorb the available boron which is then translocated to the foliage. Even though the water bath abatement system is in place, it is difficult to differentiate between current boron emissions from the factory and boron absorbed by vegetation from previously-contaminated soil.

In 1989, excessive fluoride concentrations were detected in foliage at Sites 1 and 8. Elevated concentrations of the element were found at Sites 5 and 16. In the 1990 foliage, excessive, but lower, concentrations were still present at Sites 1 and 8. At Sites 5 and 16, fluoride values had also declined (Table 3). The mean 1990 foliar fluoride concentration (10 ppm) was significantly lower than the 1989 mean level of 17 ppm.

No ULN guidelines have been established for barium. However, a relatively high concentration (48 ppm) of the element was present in the 1989 foliage at Site 1, and to a lesser extent at Sites 14 and 17 (both 20 ppm). In 1990, the barium concentration at Site 1 had increased to 58 ppm. Compared to 1989, increases in the 1990 foliage also occurred at Sites 2, 9 and 16 (Table 4). Despite these apparent variations, the mean barium concentrations were not statistically significant ($p=0.08$) between years.

Titanium concentrations detected in the 1989 and 1990 survey foliage are listed in Table 5. Comparatively elevated concentrations of the element in both years were found at Sites 1, 5, 8, and 16. Although 1990 values at Sites 5, 8, and 16 were lower than in 1989, no appreciable change was evident at other site locations. Although the mean concentration

was only marginally lower in 1990 compared to 1989 (9 ppm vs 12 ppm), this reduction was highly significant (p=0.01).

Sodium analysis was not performed on the 1989 foliage. Results from the 1990 foliage analysis (Table 6) show that sodium concentrations were slightly elevated at those sites closer to the American Standard plant. However, the high sodium value at Site 19, which is relatively far from the source, is attributed to the residual effects of road salt and not American Standard. Therefore, if American-Standard is a marginal sodium source, the environmental impact is indistinguishable from normal urban road salt use.

Foliar nickel concentrations in 1989 and 1990 are shown in Table 7. An excessive concentration of the element was present in the foliage at Site 16 in 1989 (9 ppm) and an elevated concentration (6 ppm) at Site 1. In 1990, the concentration at Site 16 was 4 ppm but essentially unchanged at Site 1. Overall, there was no statistical difference between the 1989 and 1990 mean nickel levels.

Zinc concentrations in the 1989 and 1990 foliage were all below the 250 ppm ULN guideline (Table 8). There was no consistent gradient of foliar zinc concentrations relative to distance or direction from American-Standard in either 1989 or 1990. Although the mean zinc concentration was higher in 1990, this difference was not statistically significant.

Lead concentrations detected in both the 1989 and 1990 foliage were generally very low (Table 9). There was no consistent gradient relative to American-Standard. Because the concentrations were all at or near the analytical detection limit, no statistical analyses were conducted.

None of the magnesium concentrations found in the 1989 and 1990 foliage exceeded 0.4% - well below the 0.7% ULN guideline. Because of the low values and the absence of any depositional pattern, the American Standard plant does not appear to be a source of this element (Table 10). Similarly, because of the consistently low concentrations, statistical analyses were not conducted.

Copper concentrations in foliage were slightly higher in 1989 at Sites 7 and 16 than in 1990, but otherwise, no appreciable differences between the two years is evident. In fact, the annual mean concentrations were the same (5 ppm) in both sample years. All 1989 and 1990 values were well below the ULN guideline of 20 ppm (Table 11).

Sulphur and iron concentrations detected in the 1989 and 1990 survey foliage appear in Tables 12 and 13, respectively. Values from both sample years are low and none exceeded their respective ULN guidelines. Based on the similarity of concentrations found at the sites, (i.e. no concentration gradient) American Standard does not appear to be a point source for either element. However, marginally elevated iron concentrations were found in the 1989 and 1990 foliage at Site 17. Based on locational proximity, a nearby foundry operation may be the source.

Summary

As a result of a complaint investigation conducted by the Phytotoxicology Section in 1987, the American Standard plant in Cambridge was suspected of being a source for boron and fluoride emissions. Based on the Phytotoxicology findings, American Standard installed a water bath abatement system in December, 1988 to curtail gaseous and particulate emissions from the final coat spray booth areas.

In 1989, the Phytotoxicology Section initiated a vegetation and soil survey investigation at selected sites in the vicinity of the factory in order to evaluate the extent and nature of contamination to the terrestrial environment. Analysis of survey vegetation showed that boron concentrations exceeded ULN guidelines at 11 of 17 sites. Tests also indicated that elevated or excessive concentrations of fluoride, barium, titanium, zinc and nickel and were present at sites close to the plant.

In 1990, a second vegetation surveillance was conducted in the vicinity of American Standard. In spite of the abatement equipment installed in 1988, severe boron-like injury was still observed at sites close to the factory. With increased distance from the source, the severity and incidence of injury declined in all directions. Concentrations of boron in foliage were excessive at 8 sites, most of which are located relatively close to the plant. Excessive concentrations of fluoride were found in vegetation at 2 nearby sites. In addition, elevated concentrations of barium, titanium, sodium, nickel, zinc, and copper were present in vegetation at sites close to the factory.

With respect to boron in foliage sampled in the vicinity of American Standard, it is difficult to separate the influence of historical emissions from current emissions. As a result, it is difficult to assess the effectiveness of the water bath system to abate boron emissions from the factory. Central to the problem is the fact that plant roots easily absorb boron from the soil for subsequent translocation of the element to the leaves. The translocated boron induces foliar injury and is detected by chemical analysis. Of the total amount of boron detected in the foliage in 1989 and 1990, an unknown percentage of the total would have been absorbed from the soil and the remainder from ambient emissions. Even in the absence of current emissions, plants growing in boron-contaminated soil will continue to absorb the element, cause injury to foliage and be detected by chemical analysis.

American-Standard was, in 1990, still a source of Phytotoxic boron and fluoride emissions, although the foliar data suggests that the 1990 emissions were reduced from 1989. With the exception of titanium, which was significantly lower in 1990, the foliar concentrations of the nine other elements were not significantly different in the two survey years.

In order to fully assess the efficiency of the abatement system installed in the American Standard plant, the Phytotoxicology Section implemented a moss bag monitoring program in 1991. Until data from this program are obtained, boron emissions during the post-abatement period cannot be fully determined.

TABLE: 1 Observational Notes of Surveillance Foliage Examined in the Vicinity of American-Standard, Cambridge 1990

Survey Site Number	Distance & Direction from A-S	Vegetation Examined	Observations
1	200 m NE	amur maple	11-35% terminal, marginal & intercostal necrosis on 100% of foliage.
2	400 m NE	amur maple	2-10% terminal & marginal necrosis on 95% of foliage.
3	600 m NE	Norway maple	No visible air pollution injury to foliage.
4	700 m NE	silver maple	No visible air pollution injury to foliage.
5	225 m E	Norway maple	>35% terminal, marginal & intercostal necrosis on 100% of foliage.
6	450 m E	Norway maple	No visible air pollution injury to foliarge.
7	500 m E	silver maple green ash	No visible air pollution injury to foliage. " " "
8	150 m SE	silver maple	11-35% terminal, marginal & intercostal necrosis on 100% of foliage.
8		Norway maple	11-35% terminal, marginal & intercostal necrosis on 100% of foliage.
9	300 m SE	silver maple	>0-1% terminal necrosis on scattered leaves.
10	150 m SSW	Norway maple	>0-1% terminal necrosis on scattered leaves.
11	400 m SSW	Norway maple	No visible air pollution injury to foliage.
13	400 m SW	silver maple	2-10% terminal & marginal necrosis on 25% of foliage.
14	600 m SW	Norway maple	2-10% terminal & marginal necrosis on 50% of foliage. 11-35% terminal & marginal necrosis on 20% of foliage.
15	850 m SW	silver maple	2-10% terminal & marginal necrosis on older foliage.
16	60 m N	amur maple	11-35% terminal, marginal & intercostal necrosis on all mature foliage.
17	250 m W	silver maple	>0-1% terminal necrosis on scattered leaves.
18[1]	1200 m W	silver maple Norway maple	No visible air pollution injury to foliage. No visible air pollution injury to foliage.

cont'd...

TABLE: 1 Cont'd

Survey Site Number	Distance & Direction from A-S	Vegetation Examined	Observations
19	850 m N	silver maple	No visible air pollution injury to foliage.
		Norway maple	No visible air pollution injury to foliage.
20	1300 m N	silver maple	No visible air pollution injury to foliage.
		Norway maple	No visible air pollution injury to foliage.
21	600 m NW	silver maple	No visible air pollution injury to foliage.
22[1]	7.8 km SSW	amur maple	No visible air pollution injury to foliage.

[1]Control locations.

TABLE: 2 Boron Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance& Dirction from A-S	Vegetation Species Sampled	Boron Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	895	525
2	400 m NE	Norway maple	395	525
3	600 m NE	Norway maple	270	155
4	700 m NE	silver maple	115	103
5	225 m E	Norway maple	645	305
6	450 m E	Norway maple	175	140
7	500 m E	silver maple	70	50
8	150 m SE	silver maple	595	605
8	150 m SE	Norway maple	NS	360
9	300 m SE	silver maple	240	365
10	150 m SSW	silver maple	255	230
11	400 m SSW	Norway maple	149	125
13	400 m SW	silver maple	190	120
14	600 m SW	Norway maple	270	155
15	850 m SW	silver maple	120	46
16	60 m N	amur maple	1300	1050
17	250 m W	silver maple	335	295
18[1]	1200 m W	silver maple	27	47
18	1200 m W	Norway maple	48	38
19	850 m N	silver maple	NS	82
19	850 m N	Norway maple	NS	73
20	1300 m N	silver maple	NS	53
20	1300 m N	Norway maple	NS	56
21	600 m NW	silver maple	NS	50
22[1]	7.8 km SSW	amur maple	28	41
Mean - Common Sites (t=2.46, p<0.03)			339	271
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			175	175

[1]Control locations [2]Mean of duplicate samples NS - Vegetation at this site not sampled.

t - two tailed t test value. p - probability/significance level.

TABLE: 3 Fluoride Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Fluoride Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	68	41
2	400 m NE	Norway maple	12	12
3	600 m NE	Norway maple	3	3
4	700 m NE	silver maple	4	8
5	225 m E	Norway maple	31	12
6	450 m E	Norway maple	6	3
7	500 m E	silver maple	3	3
8	150 m SE	silver maple	67	35
8	150 m SE	Norway maple	NS	66
9	300 m SE	silver maple	20	29
10	150 m SSW	silver maple	8	7
11	400 m SSW	Norway maple	5	4
13	400 m SW	silver maple	14	5
14	600 m SW	Norway maple	8	4
15	850 m SW	silver maple	3	3
16	60 m N	amur maple	33	6
17	250 m W	silver maple	14	7
18[1]	1200 m W	silver maple	4	2
18	1200 m W	Norway maple	2	2
19	850 m N	silver maple	NS	3
19	850 m N	Norway maple	NS	2
20	1300 m N	silver maple	NS	3
20	1300 m N	Norway maple	NS	2
21	600 m NW	silver maple	NS	2
22[1]	7.8 km SSW	amur maple	5	2
Mean - Common Sites (t=2.86, p<0.01)			17	10
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			35	35

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

t = two tailed t test value. p = probability/significance level.

TABLE: 4 Barium Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Barium Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	48	58
2	400 m NE	Norway maple	9	16
3	600 m NE	Norway maple	10	9
4	700 m NE	silver maple	4	6
5	225 m E	Norway maple	17	18
6	450 m E	Norway maple	7	6
7	500 m E	silver maple	2	3
8	150 m SE	silver maple	17	26
8	150 m SE	Norway maple	NS	35
9	300 m SE	silver maple	9	21
10	150 m SSW	silver maple	5	9
11	400 m SSW	Norway maple	12	13
13	400 m SW	silver maple	8	5
14	600 m SW	Norway maple	20	14
15	850 m SW	silver maple	11	10
16	60 m N	amur maple	3	28
17	250 m W	silver maple	20	18
18[1]	1200 m W	silver maple	3	4
18	1200 m W	Norway maple	8	8
19	850 m N	silver maple	NS	9
19	850 m N	Norway maple	NS	8
20	1300 m N	silver maple	NS	6
20	1300 m N	Norway maple	NS	8
21	700 m W	silver maple	NS	6
22[1]	7.8 km SSW	amur maple	3	4
Mean - Common Sites (t=1.89, p<0.08)			12	15
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			NE	NE

[1]Control locations [2]Mean of duplicate samples NS - Vegetation at this site not sampled.

NE - ULN guideline for this element has not been established.

t - two tailed t test value. p - probability/significance level.

TABLE: 5 Titanium Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Titanium Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	31	29
2	400 m NE	Norway maple	13	13
3	600 m NE	Norway maple	6	<4
4	700 m NE	silver maple	8	7
5	225 m E	Norway maple	20	12
6	450 m E	Norway maple	5	4
7	500 m E	silver maple	4	1
8	150 m SE	silver maple	19	13
8	150 m SE	Norway maple	NS	22
9	300 m SE	silver maple	9	14
10	150 m SSW	silver maple	6	5
11	400 m SSW	Norway maple	7	5
13	400 m SW	silver maple	11	6
14	600 m SW	Norway maple	8	10
15	850 m SW	silver maple	8	10
16	60 m N	amur maple	30	17
17	250 m W	silver maple	13	7
18[1]	1200 m W	silver maple	5	4
18	1200 m W	Norway maple	5	4
19	850 m N	silver maple	NS	7
19	850 m N	Norway maple	NS	6
20	1300 m N	silver maple	NS	7
20	1300 m N	Norway maple	NS	7
21	600 m NW	silver maple	NS	5
22[1]	7.8 km SSW	amur maple	8	5
Mean - Common Sites (t=2.97, p<0.01)			12	9
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			NE	NE

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

NE - ULN guideline for this element has not been established.

t = two tailed t test value. p= probability/significance level.

TABLE: 6 Sodium Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Sodium Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	NA	44
2	400 m NE	Norway maple	NA	45
3	600 m NE	Norway maple	NA	10
4	700 m NE	silver maple	NA	12
5	225 m E	Norway maple	NA	30
6	450 m E	Norway maple	NA	9
7	500 m E	silver maple	NA	6
8	150 m SE	silver maple	NA	42
8	150 m SE	Norway maple	NA	40
9	300 m SE	silver maple	NA	29
10	150 m SSW	silver maple	NA	18
11	400 m SSW	Norway maple	NA	24
13	400 m SW	silver maple	NA	49
14	600 m SW	Norway maple	NA	25
15	850 m SW	silver maple	NA	20
16	60 m N	amur maple	NA	63
17	250 m W	silver maple	NA	38
18[1]	1200 m W	silver maple	NA	7
18	1200 m W	Norway maple	NA	10
19	850 m N	silver maple	NS	11
19	850 m N	Norway maple	NS	210
20	1300 m N	silver maple	NS	10
20	1300 m N	Norway maple	NS	7
21	600 m NW	silver maple	NS	64
22[1]	7.8 km SSW	amur maple	NA	14
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			350	350

[1]Control locations [2]Mean of duplicate samples NS - Vegetation at this site not sampled.

NA - 1989 samples were not analyzed for this element.

TABLE: 7 Nickel Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Nickel Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	6	7
2	400 m NE	Norway maple	1	2
3	600 m NE	Norway maple	1	1
4	700 m NE	silver maple	1	1
5	225 m E	Norway maple	3	3
6	450 m E	Norway maple	1	1
7	500 m E	silver maple	1	1
8	150 m SE	silver maple	2	3
8	150 m SE	Norway maple	NS	4
9	300 m SE	silver maple	1	2
10	150 m SSW	silver maple	1	1
11	400 m SSW	Norway maple	1	1
13	400 m SW	silver maple	1	1
14	600 m SW	Norway maple	1	2
15	850 m SW	silver maple	1	1
16	60 m N	amur maple	9	4
17	250 m W	silver maple	2	2
18[1]	1200 m W	silver maple	1	1
18	1200 m W	Norway maple	1	1
19	850 m N	silver maple	NS	1
19	850 m N	Norway maple	NS	1
20	1300 m N	silver maple	NS	1
20	1300 m N	Norway maple	NS	1
21	600 m NW	silver maple	NS	1
22[1]	7.8 km SSW	amur maple	1	1
Mean - Common Sites (t=1.23, p<0.24)			2	2
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			7	7

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

t = two tailed t test value. p = probability/significance level.

TABLE: 8 Zinc Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Zinc Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	53	56
2	400 m NE	Norway maple	32	30
3	600 m NE	Norway maple	17	13
4	700 m NE	silver maple	33	31
5	100 m ESE	Norway maple	26	33
6	450 m E	Norway maple	12	12
7	500 m E	silver maple	32	48
8	150 m SE	silver maple	56	77
8	150 m SE	Norway maple	NS	35
9	300 m SE	silver maple	36	79
10	150 m SSW	silver maple	26	29
11	400 m SSW	Norway maple	23	23
13	400 m SW	silver maple	32	28
14	600 m SW	Norway maple	26	21
15	850 m SW	silver maple	10	39
16	60 m N	amur maple	56	55
17	250 m W	silver maple	83	73
18[1]	1200 m W	silver maple	24	21
18	1200 m W	Norway maple	13	15
19	850 m N	silver maple	NS	16
19	850 m N	Norway maple	NS	13
20	1300 m N	silver maple	NS	33
20	1300 m N	Norway maple	NS	23
21	600 m NW	silver maple	NS	23
22[1]	7.8 km SSW	amur maple	16	15
Mean - Common Sites (=1.42, p<0.17)			33	38
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			250	250

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

t = two tailed t test value. p = probability/significance level.

TABLE: 9 Lead Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Lead Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	<2	<3
2	400 m NE	Norway maple	<2	<1
3	600 m NE	Norway maple	<1	<1
4	700 m NE	silver maple	>1	<1
5	225 m E	Norway maple	<2	<2
6	450 m E	Norway maple	<1	<2
7	500 m E	silver maple	<1	<2
8	150 m SE	silver maple	<1	<1
8	150 m SE	Norway maple	NS	<2
9	300 m SE	silver maple	>1	<1
10	150 m SSW	silver maple	>1	<1
11	400 m SSW	Norway maple	<2	<1
13	400 m SW	silver maple	<2	<2
14	600 m SW	Norway maple	2	<2
15	850 m SW	silver maple	<2	<2
16	60 m N	amur maple	<4	<3
17	250 m W	silver maple	<3	<2
18[1]	1200 m W	silver maple	>1	<1
18	1200 m W	Norway maple	>1	<1
19	850 m N	silver maple	NS	<1
19	850 m N	Norway maple	NS	<1
20	1300 m N	silver maple	NS	<1
20	1300 m N	Norway maple	NS	<1
21	600 m NW	silver maple	NS	<2
22[1]	7.8 km SSW	amur maple	>2	<1
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			60	60

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

TABLE: 10 Magnesium Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Magnesium Concentration (% - dry weight)[2] 1989	1990
1	200 m NE	amur maple	0.3	0.3
2	400 m NE	Norway maple	0.2	0.2
3	600 m NE	Norway maple	0.3	0.3
4	700 m NE	silver maple	0.3	0.5
5	225 m E	Norway maple	0.2	0.3
6	450 m E	Norway maple	0.2	0.2
7	500 m E	silver maple	0.2	0.2
8	150 m SE	silver maple	0.3	0.4
8	150 m SE	Norway maple	NS	0.3
9	300 m SE	silver maple	0.2	0.4
10	150 m SSW	silver maple	0.3	0.3
11	400 m SSW	Norway maple	0.2	0.3
13	400 m SW	silver maple	0.3	0.3
14	600 m SW	Norway maple	0.3	0.3
15	850 m SW	silver maple	0.2	0.3
16	60 m N	amur maple	0.2	0.2
17	250 m W	silver maple	0.2	0.2
18[1]	1200 m W	silver maple	0.2	0.3
18	1200 m W	Norway maple	0.3	0.3
19	850 m N	silver maple	NS	0.4
19	850 m N	Norway maple	NS	0.2
20	1300 m N	silver maple	NS	0.4
20	1300 m N	Norway maple	NS	0.2
21	600 m NW	silver maple	NS	0.4
22[1]	7.8 km SSW	amur maple	0.5	0.4
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			0.7%	0.7%

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

TABLE: 11 Copper Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Copper Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	8	6
2	400 m NE	Norway maple	6	6
3	600 m NE	Norway maple	3	3
4	700 m NE	silver maple	5	3
5	225 m E	Norway maple	6	5
6	450 m E	Norway maple	5	6
7	500 m E	silver maple	10	5
8	150 m SE	silver maple	7	9
8	150 m SE	Norway maple	NS	9
9	300 m SE	silver maple	4	6
10	150 m SSW	silver maple	4	3
11	400 m SSW	Norway maple	5	5
13	600 m SW	silver maple	3	1
14	600 m SW	Norway maple	5	4
15	850 m SW	silver maple	3	8
16	60 m N	amur maple	10	7
17	250 m W	silver maple	5	4
18[1]	1200 m W	silver maple	4	4
18	1200 m W	Norway maple	5	3
19	850 m N	silver maple	NS	3
19	850 m N	Norway maple	NS	4
20	1300 m N	silver maple	NS	4
20	1300 m N	Norway maple	NS	6
21	600 m NW	silver maple	NS	7
22[1]	7.8 km SSW	amur maple	4	4
Mean - Common Sites (t=1.33, p<0.20)			5	5
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			20	20

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

t = two tailed t test value. p = probability/significance level.

TABLE: 12 Sulphur Concentrations in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Sulphur Concentration (% - dry weight)[2] 1989	1990
1	200 m NE	amur maple	0.1	0.2
2	400 m NE	Norway maple	0.1	0.1
3	600 m NE	Norway maple	0.1	0.1
4	700 m NE	silver maple	0.1	0.1
5	225 m E	Norway maple	0.2	0.2
6	450 m E	Norway maple	0.1	0.2
7	500 m E	silver maple	0.1	0.2
8	150 m SE	silver maple	0.1	0.2
8	150 m SE	Norway maple	NS	0.2
9	300 m SE	silver maple	0.1	0.2
10	150 m SSW	silver maple	0.1	0.1
11	400 m SSW	Norway maple	0.1	0.2
13	400 m SW	silver maple	0.2	0.2
14	600 m SW	Norway maple	0.1	0.2
15	850 m SW	silver maple	0.1	0.3
16	60 m N	amur maple	0.1	0.1
17	250 m W	silver maple	0.1	0.1
18[1]	1200 m W	silver maple	0.1	0.2
18	1200 m W	Norway maple	0.1	0.2
19	850 m N	silver maple	NS	0.2
19	850 m N	Norway maple	NS	0.2
20	1300 m N	silver maple	NS	0.2
20	1300 m N	Norway maple	NS	0.2
21	600 m NW	silver maple	NS	0.2
22[1]	7.8 km SW	amur maple	0.1	0.1
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			0.4%	0.4%

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

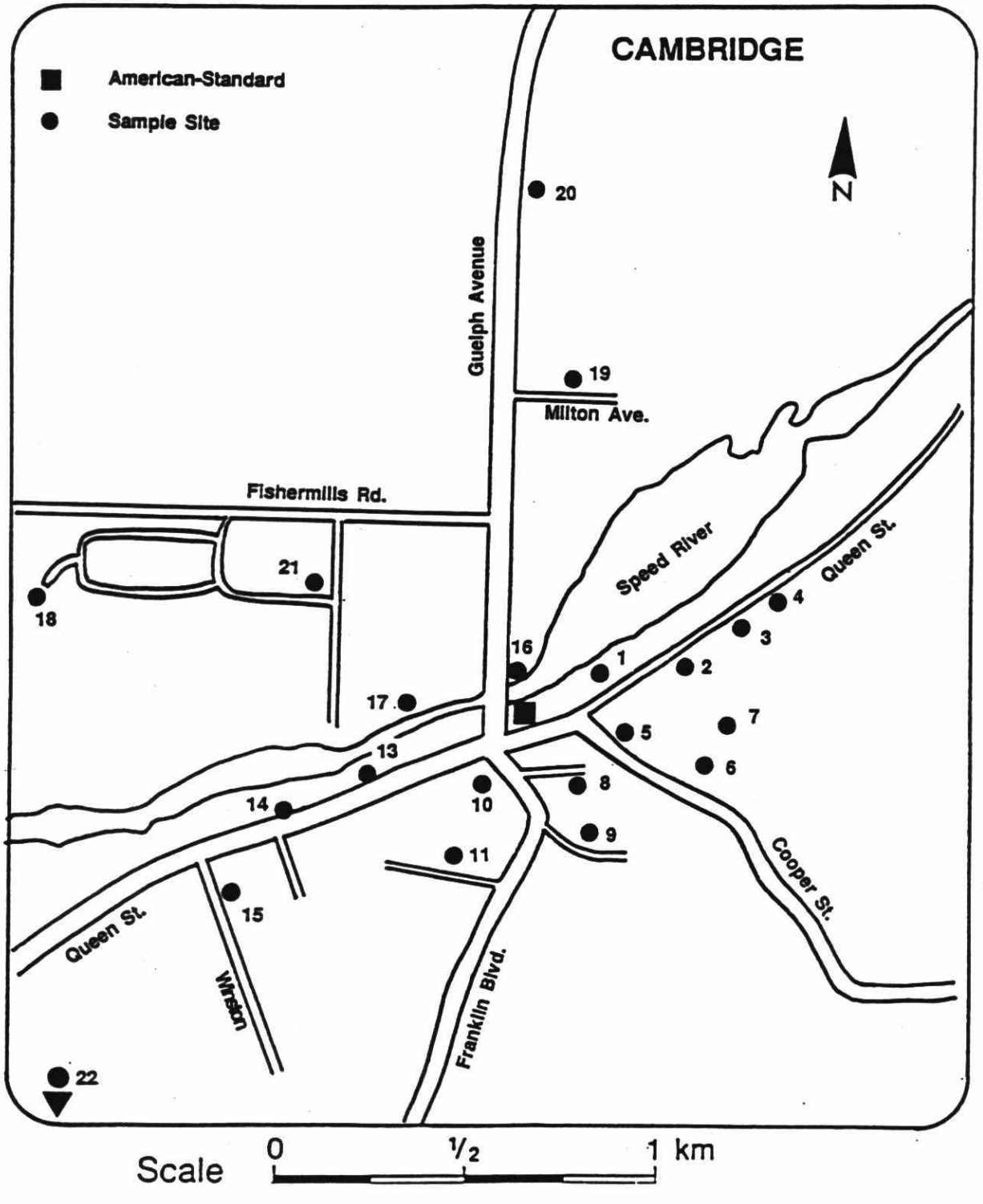
TABLE: 13 Iron Concentrations Detected in Unwashed Foliage Collected in the Vicinity of American-Standard, Cambridge 1989 & 1990

Sample Site Number	Distance & Dirction from A-S	Vegetation Species Sampled	Iron Concentration (ppm - dry weight)[2] 1989	1990
1	200 m NE	amur maple	175	175
2	400 m NE	Norway maple	105	130
3	600 m NE	Norway maple	130	83
4	700 m NE	silver maple	115	95
5	225 m E	Norway maple	135	115
6	450 m E	Norway maple	95	83
7	500 m E	silver maple	130	90
8	150 m SE	silver maple	115	97
8	150 m SE	Norway maple	NS	145
9	300 m SE	silver maple	90	125
10	150 m SSW	silver maple	70	72
11	400 m SSW	Norway maple	100	94
13	400 m SW	silver maple	120	89
14	600 m SW	Norway maple	100	145
15	850 m SW	silver maple	120	113
16	60 m N	amur maple	225	190
17	250 m W	silver maple	505	470
18[1]	1200 m W	silver maple	95	84
18	1200 m W	Norway maple	95	74
19	850 m N	silver maple	NS	110
19	850 m N	Norway maple	NS	90
20	1300 m N	silver maple	NS	110
20	1300 m N	Norway maple	NS	110
21	600 m NW	silver maple	NS	101
22[1]	7.8 km SSW	amur maple	140	110
Mean - Common Sites (t=1.69, p<0.11)			140	129
Phytotoxicology Upper Limit of Normal Guideline for Unwashed Urban Foliage			1000	1000

[1]Control locations [2]Mean of duplicate samples. NS - Vegetation at this site not sampled.

t = two tailed t test value. p = probability/significance level.

Location of Vegetation Survey Sites in the
Vicinity of American-Standard, Cambridge - 1990.



Appendix

Derivation and Significance of MOE "Upper Limits of Normal" Contaminant Guidelines

The MOE "upper limits of normal" contaminant guidelines essentially represent the expected maximum concentration of contaminants in surface soil (non-agricultural), foliage (tree and shrub), grass, moss bags and/or snow from areas of Ontario not subject to the influence of point source emissions. "Urban" guidelines are based upon samples collected from centres of minimum 10,000 population. "Rural" guidelines are based upon samples collected by MOE personnel using standard sampling techniques (ref: Ministry of the Environment, 1983. Field Investigation Manual. Phytotoxicology Section - Air Resources Branch: Technical Support Sections - NE and NW Regions). Chemical analyses were performed by the MOE Laboratory Services Branch.

The guidelines were calculated by taking the arithmetic mean of available analytical data and adding three standard deviations of the mean. For those distributions that are "normal", 99% of all contaminant levels in samples from "background" locations (i.e. not affected by point sources nor agricultural activities) will lie below these upper limits of normal. For those distributions that are non-normsl, the calculated upper limits of normal will not actually equal the 99th percentile, but nevertheless they lie within the observed upper range of MOE results for Ontario samples.

It is stressed that these guidelines do not represent maximum desirable or allowable levels of contaminants. Rather, they serve as levels which, if exceeded, would prompt further investigation on a case by case basis to determine the significance, if any, of the above normal concentration(s). Concentrations which exceed the guidelines are not necessarily toxic to plants, animals or man. Concentrations which are below the guidelines are not known to be toxic.